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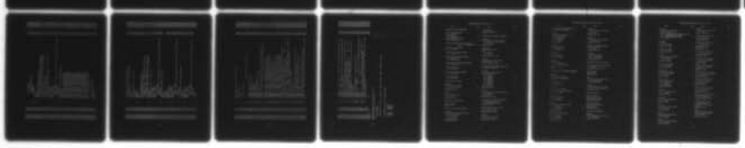

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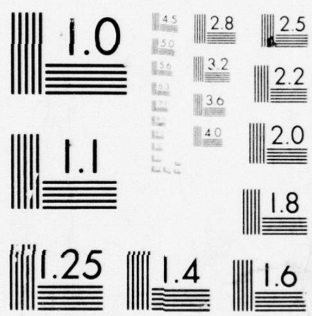

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TECHNICAL REPORT ARCSL-TR-77035

(EO-TR-76102)

A COMPUTER PROGRAM FOR THE ANALYSIS OF MACROINVERTEBRATE DATA FROM WATER QUALITY SURVEYS

by

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Environmental Technology Division

May 1977

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
Chemical Systems Laboratory
Aberdeen Proving Ground, Maryland 21010

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DICALC	Water quality surveys

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An original DICALC program has been revised to calculate species diversity (using three methods) and relative abundance, absolute abundance, and density of each species collected at a sampling station. The new program has greater flexibility and utility for examining differences between aquatic community samples than the original DICALC. The procedures and options for DICALC are explained and the program is given in the appendix.

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PREFACE

The work described in this report was authorized under Task 2, Subproject 3 of PAA 5764114, Development of Methods to Minimize Environmental Contamination, Ecological Surveys of Environmental Conditions at USAMC Installations.

The use of trade names in this report does not constitute an official endorsement or approval of the use of such commercial hardware or software. This report may not be cited for purposes of advertisement.

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SUMMARY

In the course of analysis of macroinvertebrate data obtained during ecological surveys conducted during the project, a scheme of data analysis was developed. The following report describes a computer program developed to perform a portion of this data analysis.

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A COMPUTER PROGRAM FOR THE ANALYSIS OF MACROINVERTEBRATE DATA FROM WATER QUALITY SURVEYS

I. INTRODUCTION.

The structure and organization of biological communities are of great interest to scientists involved in the study of these communities. Community analysis has long been a part of the field of pollution biology because one of the basic assumptions of community analysis is that polluted communities have different species occurrences and abundances than nonpolluted communities. Species diversity and density measurements are routinely made by pollution biologists during pollution surveys. The following is a description of a computer program that calculates some of these parameters.

II. SPECIES DIVERSITY MEASURES.

A. Shannon Diversity Index.

The Shannon diversity index is derived from information theory[1-3] as

$$\bar{d} = -\sum_{i=1}^{k} \frac{n_i}{n} \log_2 \frac{n_i}{n} \tag{1}$$

where n is the total number of individuals in k species, and n_i is the number of individuals in the ith species. The relative maximum of $\bar{d}$ is assumed when the $n_i (i = 1, \ldots, k)$ are uniformly distributed within the community, hence

$$\bar{d}_{\max} = \log_2 k \tag{2}$$

The relative minimum is calculated according to

$$\bar{d}_{\min} = \log_2 n - \left(1 - \frac{k+1}{n}\right) \log_2 (n - k + 1) \tag{3}$$

The relative efficiency, synonymous with the normed version of $\bar{d}$, or evenness,[4] is the measure of the ratio of the sample distribution of n_i to the theoretical uniform distribution of n_i in n:

$$\hat{\bar{d}} = \frac{1}{\log_2 k} \sum_{i=1}^{k} \frac{n_i}{n} \log_2 \frac{n_i}{n} \tag{4}$$

The redundancy is the complement of the efficiency:

$$\hat{\bar{d}}_r = 1 - \hat{\bar{d}} \tag{5}$$

B. Simpson Diversity Index.

The Simpson diversity index is defined as[5]

$$S = 1 - \sum_{i=1}^{k} \frac{n_i(n_i - 1)}{n(n-1)} \tag{6}$$

where

$$n > 1$$

and

$$\sum_{i=1}^{k} n_i = n$$

The relative maximum and minimum are calculated according to the following equations:

$$S_{\max} = \frac{n(k-1)}{k(n-1)} \tag{7}$$

$$S_{\min} = \left(2 - \frac{k}{n}\right)\left(\frac{k-1}{n-1}\right) \tag{8}$$

The normed version of equation 6 is

$$\hat{S} = \frac{1}{n(1 - 1/k)} \left[(n-1) - \sum_{i=1}^{k} \frac{n_i}{n} (n_i - 1) \right] \tag{9}$$

and the redundancy is again the complement of the normed version of the diversity index,

$$\hat{S}_r = 1 - \hat{S}$$

C. McIntosh Diversity Index.

The McIntosh diversity index assumes samples are taken from an infinite population, where each sample contains n individuals in k different species present, n_i individuals in the ith species, and

$$\sum_{i=1}^{k} n_i = n$$

The Euclidean measure is

$$\Delta = \left(\sum_{i=1}^{k} p_i^2\right)^{1/2} \tag{10}$$

where p_i is the proportion of individuals that belong to the ith species,

$$\sum_{i=1}^{k} p_i = 1$$

and where $1/k \leqslant \Delta \leqslant 1$.

The McIntosh measure of species diversity is then defined to be

$$U = 1 - \Delta \tag{11}$$

As each $p_i \rightarrow 1/k$, U attains its relative maximum,

$$U_{max} = 1 - \frac{1}{\sqrt{k}} \tag{12}$$

The relative minimum is attained according to the least uniformly distributed combination of the $n_i (i = 1, 2, \ldots, k)$ in n:

$$U_{min} = \frac{k - 1 + \sqrt{k-1}}{n} \tag{13}$$

The ratio of the calculated species diversity U to its relative maximum U_{max} is the normed version of U:

$$\hat{U} = \frac{1}{1 - 1/\sqrt{k}} \left[1 - \left(\sum_{i=1}^{k} p_i^2\right)^{1/2}\right] \tag{14}$$

The redundancy (the measure of the deviation of sample distribution with respect to the true uniform distribution) is again the complement of the normed version:

$$\hat{U}_r = 1 - \hat{U} \tag{15}$$

III. DESCRIPTION OF DICALC PROGRAM.

The FORTRAN V program DICALC (see appendix) was developed for analysis of biological data and comparison of population and ecological studies.[7] DICALC originally included complete calculations of species occurrence, relative abundance at a sample station, and measures of

species diversity for analysis of the sample distribution. In addition to these listings, the new version of DICALC includes the computations for the approximate density of the species at each station and for the relative and absolute abundance of each of the species. DICALC also calculates the grand total for all of the stations, determines the overall species diversity, the relative and absolute abundances, and the approximate density of each species in the sampling area.

DICALC can accommodate a maximum of 150 samples and 60 different species. If greater numbers of either are necessary, the program may be easily modified by use of the parameters NSIZE and MSPEC, the maximum number of samples and the maximum number of species, respectively. By changing the value of either or both parameters, the amount of storage is changed without further modifications to the program.

The following is a list of FORTRAN variables used in this version of DICALC listed in the order entered for input and in the order printed for output:

Variable name	Description	Type
Input		
NS	Number of different species present	I5
NSS	Number of stations	I5
ISS(J)	Number of substations for each station	16I5
TITLE	Site location	12A6
PROG	Data to be considered	A6
METHOD	Type of sampling method	A6
AREA	Numerical surface area of sampler	F10.6
STAT	Station names	5A6
SPEC	Species names	5A6
JM	Species numbers	I2
FMT	Format by which to read data	13A6, A2
Output		
X(I,J)	Data matrix	See FMT
NPA	Number of individuals per unit area for each station	F10.2
TNPA	Total number of individuals per unit area	F10.2
AA	Absolute abundance	F10.2
XN	Number of individuals for each station	F10.0
XP	Relative abundance	F10.2
XS	Number of species present at each station	F10.0
H	Shannon diversity index (designated $\bar{d}$ in section II.A)	F10.4
HM	Relative maximum	F10.4
HMI	Relative minimum	F10.4
HE	Relative efficiency (normed index)	F10.4
HRR	Redundancy	F10.4
SL	Simpson lambda	F10.4
S	Simpson diversity index	F10.4
SM	Relative maximum	F10.4
SMI	Relative minimum	F10.4

Variable name	Description	Type
SE	Relative efficiency (normed index)	F10.4
SRR	Redundancy	F10.4
UD	McIntosh delta	F10.4
U	McIntosh diversity index	F10.4
UM	Relative maximum	F10.4
UMI	Relative minimum	F10.4
UE	Relative efficiency (normed index)	F10.4
URR	Redundancy	F10.4

IV. DESCRIPTION OF PROGRAM OPTIONS.

A. Sampling Methods.

Three frequently used methods of collecting macroinvertebrates are programmed into DICALC. One of these methods may be selected for the calculations of the number of individuals per unit area. If, however, none of these three standard sampling methods is used, the numerical value of the surface area of the sampler may be read in as a variable.

The following options may be selected for the METHOD variable:

1. EKMAN–This option is for the use of any 6- by 6-inch grab method. The total area of the grab is 0.02323 m^2.

2. SURBER–This option is for the use of any 12- by 12-inch bottom-sampling method. The area of the sampler is 0.09290 m^2.

3. DENDY–This option is for the Hester-Dendy multiplate samplers. This method uses eight 7.75- by 7.75-cm plates, each 0.3 cm apart, and seven 2.60- by 2.60-cm spacers. The surface area is 0.08664 m^2.

4. OTHER–This is for any collection method in which the total sampling area is known and given.

B. Data To Be Considered.

The following options may be selected for the PROG variable:

1. TOTALS–With the "TOTALS" option, the program calculates the number of individuals per unit area, the relative abundance, the absolute abundance, and the different diversity measures for the station totals.

2. SUBTOT–With the "SUBTOT" option, the program calculates the number of individuals per unit area, the relative abundance, the absolute abundance, the different diversity measures for each replicate in the sampling station, and the overall station total.

3. CSR1–The "CSR1" option calls the subroutine CSR, which calculates the cumulative sums of the replicates for each station. The program then uses these cumulative sums to calculate the cumulative number of individuals per unit area, the relative abundance, and the different diversity measures. With the addition of each replicate, the change in diversity and the number of species present can be seen. This option is also useful in determining the number of replicates that adequately sample the biological community.

V. DESCRIPTION OF DATA CARDS.

A. Title Card.

The title card shown in figure 1 includes location, sample station, date, and method of sampling in format 12A6.

B. Program Option Cards.

If using EKMAN, DENDY, or SURBER method of sampling, the card shown in figure 2 is used. If, however, the numerical value for the surface area is to be read in, then the card shown in figure 3 is used.

C. Number of Substations in Each Station.

The number of replicates at each station must be supplied in the card format shown in figure 4.

There must be the same number of entries as there are stations (ISS(J) where J = 1, . . ., NSS). Use as many cards as necessary to include all substations.

D. Station or Substation Name Cards.

The number of these cards must equal the number of stations if PROG equals TOTALS, must equal the number of substations if PROG equals CSR1, and must equal the number of sub-

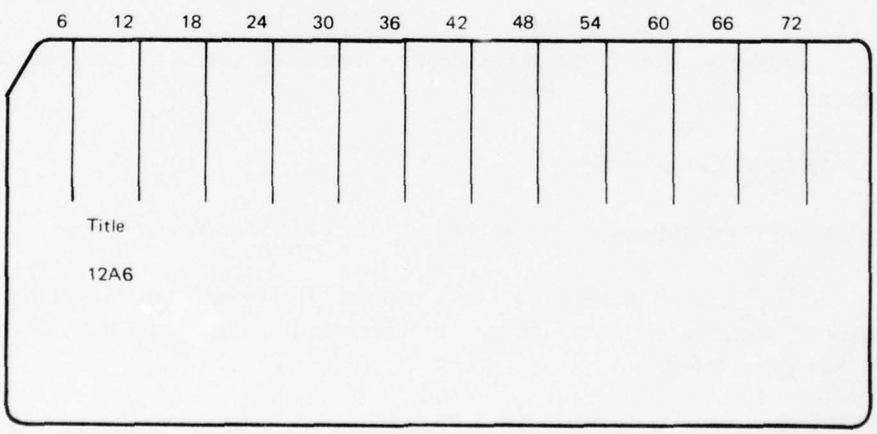

Figure 1. Title Card

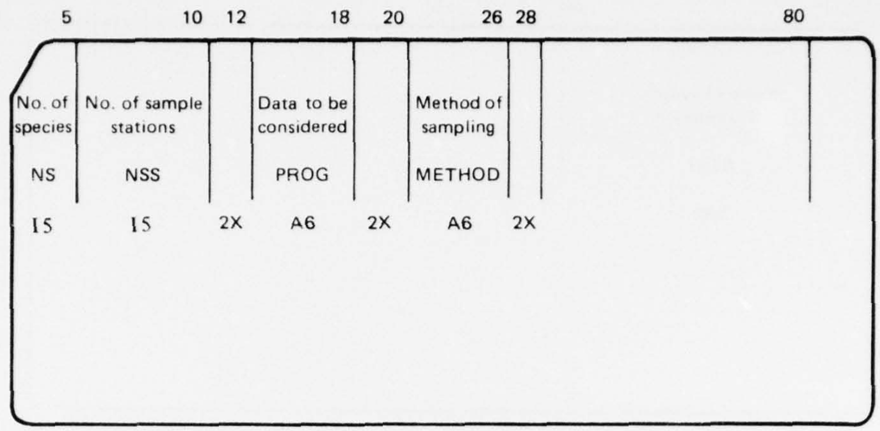

Figure 2. Program Option Card

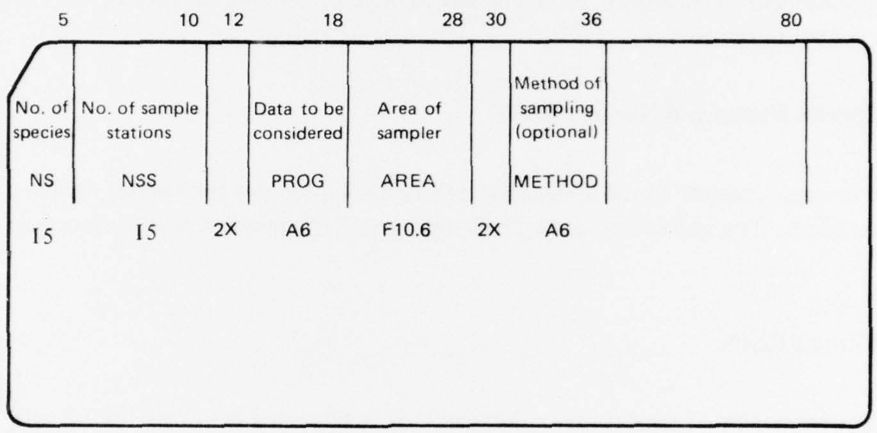

Figure 3. Alternative Sampling Method Option Card

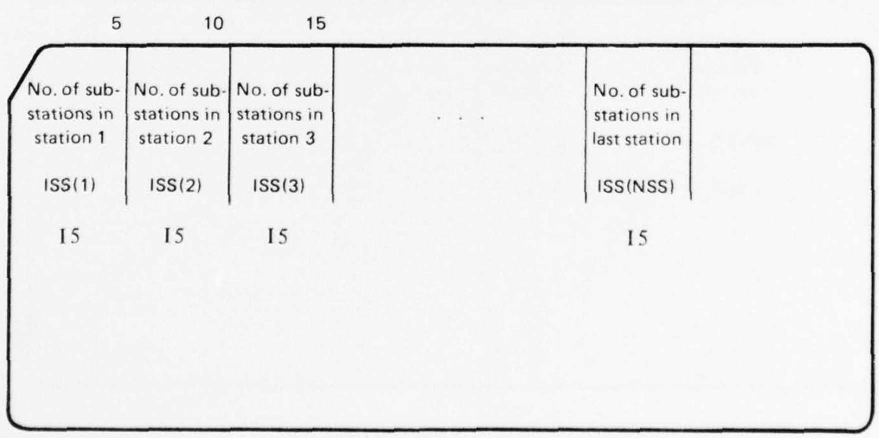

Figure 4. Substation Number Card

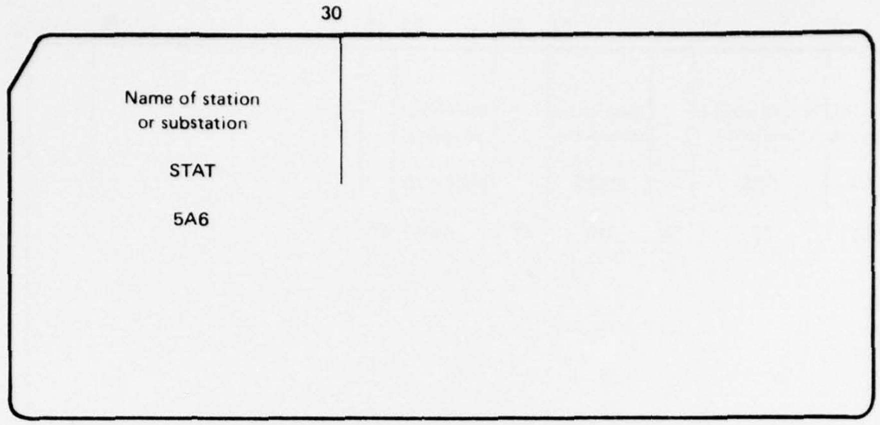

Figure 5. Station/Substation Name Card

stations plus the number of stations if PROG equals SUBTOT. The appearance of station/substation name cards is shown in figure 5.

E. **Species Names and Number Cards.**

For each species, a card appearing as in figure 6 provides the species name and a 2-digit number as identifiers. The number of these cards must equal the number of different species present (NS).

F. **Format Cards.**

The format by which data are to be read in is determined from the format card (figure 7). Two format cards must be included in the card set even if the format instructions only use one.

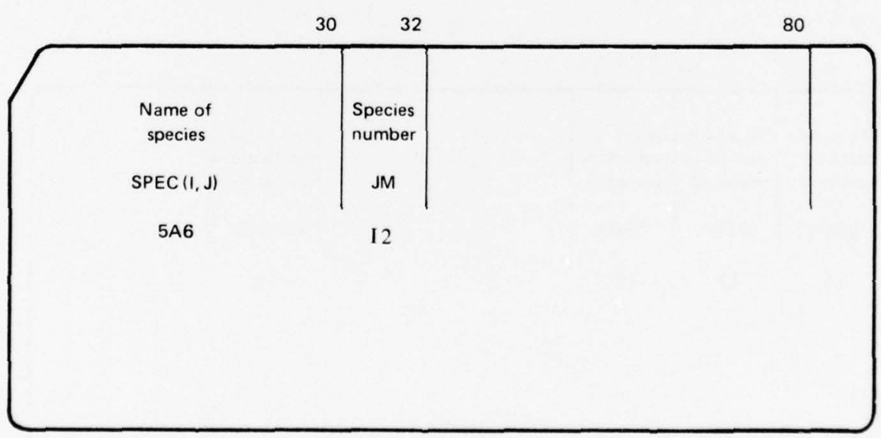

Figure 6. Species Name/Number Card

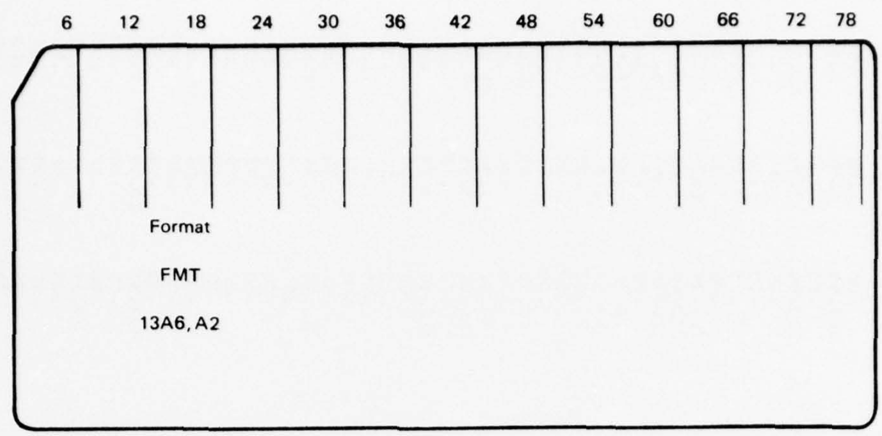

Figure 7. Format Card

G. Data Cards.

Data are read into a data matrix according to the format cards described in the preceding section. There must be at least as many data cards as there are species name cards; i.e., there must be at least one individual present for each species named.

VI. ARRANGEMENT OF DICALC PROGRAM.

The order in which program card sets appear in the card deck is as follows:

Card set	Description
1	Job control cards
2	DICALC–main program deck
3	Control card(s)
4	CSR subroutine
5	Title card
6	Option card
7	Substation card
8	Station/substation name card
9	Species name
10	Format cards
11	Data cards
Final	End of file control card

VII. SAMPLE OUTPUT.

A sample of the output from DICALC is shown in figure 8.

SAAP JUNE 75 MODIFIED SURBER

	SPECIES NAME	SPOON CREEK 1-I NO.	NO. INDIVIDUALS	RA	AA	SPOON CREEK 1-II NO.	NO. INDIVIDUALS	RA	AA
1	CHIRONOMUS SP	0.	.00	.00	.00	0.	.00	.00	.00
2	CRICOTOPUS SP	10.	107.64	2.49	13.51	17.	182.99	8.06	22.97
3	CRYPTOCHIRONOMUS SP	0.	.00	.00	.00	0.	.00	.00	.00
4	DICROTENDIPES SP	2.	21.53	.50	6.25	10.	107.64	4.74	31.25
5	EUKIEFFERIELLA SP	0.	.00	.00	.00	0.	.00	.00	.00
6	GLYPTOTENDIPES SP	0.	.00	.00	.00	0.	.00	.00	.00
7	MICROTENDIPES SP	2.	21.53	.50	1.27	3.	32.29	1.42	1.91
8	PARACHIRONOMUS SP	0.	.00	.00	.00	0.	.00	.00	.00
9	PENTANEURA SP	8.	86.11	2.00	4.52	14.	150.70	6.64	7.91
10	POLYPEDILUM SP	50.	538.21	12.47	15.58	31.	333.69	14.69	9.66
11	PROCLADIUS SP	4.	43.06	1.00	26.67	1.	10.76	.47	6.67
12	PSECTROCLADIUS SP	0.	.00	.00	.00	0.	.00	.00	.00
13	PSEUDOCHIRONOMUS SP	2.	21.53	.50	7.14	1.	10.76	.47	3.57
14	RHEOTANYTARSUS SP	5.	53.82	1.25	13.51	6.	64.59	2.84	16.22
15	STRICTOCHIRONOMUS SP	3.	32.29	.75	11.54	2.	21.53	.95	7.69
16	TANYTARSUS SP	0.	.00	.00	.00	0.	.00	.00	.00
17	CORYNEURA SP	0.	.00	.00	.00	0.	.00	.00	.00
18	CERATOPOGONIDAE	0.	.00	.00	.00	1.	10.76	.47	16.67
19	CHAOBORUS SP	7.	75.35	1.75	29.17	0.	.00	.00	.00
20	CHRYSOPS SP	0.	.00	.00	.00	4.	43.06	1.90	21.05
21	SIMULIUM SP	84.	904.20	20.95	21.37	21.	226.05	9.95	5.34
22	ANTHIPSODES SP	0.	.00	.00	.00	0.	.00	.00	.00
23	CHEUMATOPSYCHE SP	128.	1377.83	31.92	4.26	29.	312.16	13.74	.96
24	HYDROPTILA SP	0.	.00	.00	.00	0.	.00	.00	.00
25	NEOPERLA SP	0.	.00	.00	.00	0.	.00	.00	.00
26	PERLESTA PLACIDA	0.	.00	.00	.00	0.	.00	.00	.00
27	PLECOPTERA UNK	0.	.00	.00	.00	0.	.00	.00	.00
28	BAETIS SP	2.	21.53	.50	1.68	0.	.00	.00	.00
29	CAENIS SP	1.	10.76	.25	1.23	6.	64.59	2.84	7.41
30	ISONYCHIA SP	0.	.00	.00	.00	0.	.00	.00	.00
31	STENONEMA SP	0.	.00	.00	.00	0.	.00	.00	.00
32	TRICORYTHODES SP	0.	.00	.00	.00	0.	.00	.00	.00
33	CORYDALUS SP	0.	.00	.00	.00	0.	.00	.00	.00
34	CORIXIDAE	0.	.00	.00	.00	0.	.00	.00	.00
35	HEMIPTERA UNK	0.	.00	.00	.00	0.	.00	.00	.00
36	DUBIRAPHIA SP	0.	.00	.00	.00	0.	.00	.00	.00
37	HYDROPHILUS SP	0.	.00	.00	.00	0.	.00	.00	.00
38	STENELMIS SP	55.	592.03	13.72	2.38	43.	462.86	20.38	1.86
39	ASTACIDAE	1.	10.76	.25	3.33	0.	.00	.00	.00
40	HYALLELA AZTECA	0.	.00	.00	.00	0.	.00	.00	.00
41	LICERUS SP	0.	.00	.00	.00	3.	32.29	1.42	33.33
42	HIRUDINEA UNK	1.	10.76	.25	4.55	0.	.00	.00	.00
43	SPHAERIUM SP	0.	.00	.00	.00	0.	.00	.00	.00
44	FERRISSIA KIRKLANDI	0.	.00	.00	.00	0.	.00	.00	.00
45	LYMNAEA SP	0.	.00	.00	.00	0.	.00	.00	.00
46	PHYSA HAWNII	18.	193.76	4.49	20.45	7.	75.35	3.32	7.95
47	BRANCHIURA SOWERBYI	0.	.00	.00	.00	0.	.00	.00	.00
48	OLIGOCHAETE SP	17.	182.99	4.24	7.42	12.	129.17	5.69	5.24

Figure 8. Sample Output From DICALC Program

49 ATHERIX SP	1.	10.76	.25	14.29	0.	.00	.00	.00
50 COLLEMBOLA SP	0.	.00	.00	.00	0.	.00	.00	.00
51 PERICOMA SP	0.	.00	.00	.00	0.	.00	.00	.00
52 ARGIA MOESTA	0.	.00	.00	.00	0.	.00	.00	.00
53 ISCHNURA SP	0.	.00	.00	.00	0.	.00	.00	.00
TOTAL INDIVIDUALS	401.	4316.47			211.	2271.26		
TOTAL ABSOLUTE ABUNDANCE				210.13				207.67
SPECIES PRESENT	20.				18.			
SHANNON INDEX $\bar{d}$	2.9445				3.5067			
LOG(2) S	4.3219				4.1699			
RELATIVE MINIMUM	.4764				.7335			
EFFICIENCY	.6813				.8409			
REDUNDANCY	.3187				.1591			
SIMPSON INDEX S	.8163				.8923			
SIMPSON LAMDA	.1857				.1119			
RELATIVE MAXIMUM	.9524				.9489			
RELATIVE MINIMUM	.0926				.1550			
EFFICIENCY	.8572				.9403			
REDUNDANCY	.1428				.0597			
VARIANCE(N<25)	.000000				.000000			
VARIANCE(N>25)	.000334				.000260			
MCINTOSH INDEX U	.5691				.6654			
MCINTOSH DELTA	.4309				.3346			
RELATIVE MAXIMUM	.7764				.7643			
RELATIVE MINIMUM	.0583				.1001			
EFFICIENCY	.7330				.8707			
REDUNDANCY	.2670				.1293			

Figure 8 (Concluded). Sample Output From DICALC Program

VIII. CONCLUSION.

Macroinvertebrate communities are commonly analyzed by calculating species diversity and relative abundance. With the modifications presented here, DICALC, using these widely accepted methods, permits the user to swiftly calculate species diversity and relative abundance. In addition, data can be expressed in standard density units (number of individuals per square meter). The additional calculations of relative efficiency, redundancy, and relative maximum and minimum help the user to identify peculiarities about the distribution of individuals in each sample. Absolute abundance shows the proportion of individuals of a particular species collected in one of the samples during a study. This information permits the user to evaluate the numerical significance of any species in any sample. DICALC is a versatile program that is very helpful in investigating differences in community structure between sampling sites. When these data are correlated with environmental factors such as water quality, cause-and-effect relationships can be determined.

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APPENDIX

DICALC PROGRAM LISTING

```
00100    C      DICALC PROGRAM FOR THE ANALYSIS OF MACROINVERTIBRATES FROM WATER       000000
00100    C      QUALITY SURVEYS.                                                       000000
00100    C                                                                             000000
00101           COMPILER (DIAG=3), (XM=1)                                              000000
00103           PARAMETER NSIZE=150                                                    000024
00105           PARAMETER MSPEC=60                                                     000024
00106           DIMENSION TITLE(12),FMT(28),SPEC(5,MSPEC),X(MSPEC,NSIZE),XP(MSPEC,     000024
00106          1NSIZE),XN(NSIZE),XS(NSIZE),H(NSIZE),HM(NSIZE),HE(NSIZE),HRR(NSIZE)     000024
00106          2,HMI(NSIZE),XHM(NSIZE),S(NSIZE),SL(NSIZE),SM(NSIZE),SMI(NSIZE),        000024
00106          3SE(NSIZE),SRR(NSIZE),U(NSIZE),UD(NSIZE),UE(NSIZE),UM(NSIZE),           000024
00106          4UMI(NSIZE),URR(NSIZE),STAT(5,NSIZE),TNPA(NSIZE)                        000024
00107           COMMON NPA(MSPEC,NSIZE),AA(MSPEC,NSIZE),ISS(NSIZE)                     000024
00110           REAL NPA                                                               000024
00110    C                                                                             000024
00110    C      READ TITLE AND PROGRAM OPTIONS CARD                                    000024
00110    C                                                                             000024
00111           READ (5,73) TITLE                                                      000024
00114           WRITE (6,77) (TITLE(L),L=1,12)                                         000034
00117           READ (5,74) NS,NSS,PROG,METHOD                                         000044
00117    C                                                                             000044
00117    C      IF USING THE ECKMAN METHOD, AREA=.02323 SQUARE METERS                  000044
00117    C                                                                             000044
00125           IF (METHOD.EQ.'ECKMAN') GO TO 4                                        000055
00125    C                                                                             000055
00125    C      DENDY METHOD USING 8 PLATES 7.75 X 7.75 SQUARE CENTIMETERS,            000055
00125    C      SPACERS 2.60 X 2.60 SQUARE CENTIMETERS                                 000055
00125    C      SPACE BETWEEN PLATES IS .3 CENTIMETERS                                 000055
00125    C      AREA=.08664 SQUARE METERS                                              000055
00125    C                                                                             000055
00127           IF (METHOD.EQ.'DENDY ') GO TO 3                                        000060
00127    C                                                                             000060
00127    C      IF USING THE SURBER METHOD, AREA=.09290 SQUARE METERS                  000060
00127    C                                                                             000060
00131           IF (METHOD.EQ.'SURBER') GO TO 2                                        000063
00133           READ (30,96,ERR=1) NS,NSS,PROG,AREA,METHOD                             000066
00142           GO TO 5                                                                000101
00143    1      WRITE (6,117)                                                          000103
00145           GO TO 71                                                               000107
00146    2      AREA=.09290                                                            000111
00147           GO TO 5                                                                000112
00150    3      AREA=.08664                                                            000114
00151           GO TO 5                                                                000115
00152    4      AREA=.02323                                                            000117
00153           GO TO 5                                                                000120
00154    5      CONTINUE                                                               000122
00155           READ (5,102) (ISS(J),J=1,NSS)                                          000122
00163           NSS3=NSS                                                               000137
00164           NSS2=0                                                                 000141
```

```
00165               DO 6 J=1,NSS                                  000146
00170               NSS2=ISS(J)+NSS2                              000146
00171        6      CONTINUE                                      000151
00173            IF (PROG.EQ.'TOTALS') GO TO 9                    000151
00175            IF (PROG.EQ.'SUBTOT') GO TO 7                    000154
00177            IF (PROG.EQ.'CSR1  ') GO TO 8                    000157
00201            WRITE (6,103)                                    000162
00203            WRITE (6,72) PROG                                000167
00206            GO TO 71                                         000175
00207        7   CONTINUE                                         000177
00210            NSS=NSS2+NSS                                     000177
00211            GO TO 9                                          000201
00212        8   CONTINUE                                         000203
00213            NSS=NSS2                                         000203
00214        9   CONTINUE                                         000205
00214        C                                                    000205
00214        C   READ IN THE STATION NAMES                        000205
00214        C                                                    000205
00215               DO 10 I=1,NSS                                 000205
00220               READ (5,111) (STAT(L,I),L=1,5)                000221
00226        10     CONTINUE                                      000235
00226        C                                                    000235
00226        C   READ IN TAXA                                     000235
00226        C                                                    000235
00230               DO 11 I=1,NS                                  000235
00233               READ (5,75) (SPEC(L,I),L=1,5),JM              000235
00242        11     CONTINUE                                      000250
00242        C                                                    000250
00242        C   READ IN DATA FORMAT CARD                         000250
00242        C                                                    000250
00244            READ (5,76) FMT                                  000250
00244        C                                                    000250
00244        C   READ IN DATA MATRIX                              000250
00244        C                                                    000250
00247               DO 12 I=1,NS                                  000263
00252               READ (5,FMT) (X(I,J),J=1,NSS)                 000263
00260        12     CONTINUE                                      000277
00260        C                                                    000277
00260        C   WRITE THE DATA MATRIX                            000277
00260        C                                                    000277
00262            IS=0                                             000277
00263            ICOUNT=0                                         000300
00264            ICOL=0                                           000301
00265            NUMP=NSS/25+1                                    000302
00266            ISTART=1                                         000307
00267               DO 16 K=1,NUMP                                000314
00272               ICOUNT=NSS-ICOL                               000314
00273               ICHECK=MIN0(25,ICOUNT)                        000316
```

```
00274                IF (ICHECK.EQ.ICOUNT) GO TO 13                            000323
00276                ICHECK=ICOL+25                                             000325
00277                GO TO 14                                                   000330
00300        13      ICHECK=ICOL+ICOUNT                                         000332
00301        14         DO 15 I=1,NS                                            000335
00304                   WRITE (6,98) (X(I,J),J=ISTART,ICHECK)                   000352
00312        15         CONTINUE                                                000366
00314                ISTART=ISTART+25                                           000366
00315                ICOL=ICOL+25                                               000371
00316        16      CONTINUE                                                   000375
00320             IF (PROG.EQ.'TOTALS') GO TO 25                                000375
00322             IF (PROG.EQ.'SUBTOT') GO TO 17                                000400
00324             IF (PROG.EQ.'CSR1  ') GO TO 21                                000403
00326        17   CONTINUE                                                      000407
00326        C                                                                  000407
00326        C    DETERMINE THE NO. OF INDIVIDUALS PER UNIT AREA FOR THE SUBSTATIONS 000407
00326        C    AND TOTALS                                                    000407
00326        C                                                                  000407
00327                DO 20 J=1,NS                                               000407
00332                N=1                                                        000416
00333                MM=ISS(1)                                                  000420
00334                   DO 19 I=1,NSS3                                          000430
00337                      DO 18 K=N,MM                                         000456
00342                      NPA(J,K)=X(J,K)/AREA                                 000456
00343        18            CONTINUE                                             000461
00345                   NPA(J,MM+1)=X(J,MM+1)/(AREA*ISS(I))                     000461
00346                   N=MM+2                                                  000472
00347                   MM=MM+ISS(I+1)+1                                        000475
00350        19         CONTINUE                                                000504
00352        20      CONTINUE                                                   000504
00354             GO TO 28                                                      000504
00355        21   CONTINUE                                                      000506
00356             CALL CSR (ISS,NSS3,X,NSIZE,NS,MSPEC)                          000506
00356        C                                                                  000506
00356        C    DETERMINE THE NO. OF INDIVIDUALS PER UNIT AREA FOR THE CUMULATIVE 000506
00356        C    SUMS OF REPLICATES                                            000506
00356        C                                                                  000506
00357                DO 24 J=1,NS                                               000515
00362                N=1                                                        000525
00363                MM=ISS(1)                                                  000527
00364                   DO 23 I=1,NSS3                                          000535
00367                   II=1                                                    000545
00370                      DO 22 K=N,MM                                         000555
00373                      NPA(J,K)=X(J,K)/(AREA*II)                            000555
00374                      II=II+1                                              000563
00375        22            CONTINUE                                             000567
00377                   N=MM+1                                                  000567
00400                   MM=MM+ISS(I+1)                                          000572
```

```
00401    145*   23          CONTINUE                                                  145    000600
00403    146*   24       CONTINUE                                                     146    000600
00405    147*         GO TO 28                                                        147    000600
00405    148*   C                                                                     148    000600
00405    149*   C       DETERMINE THE NO. OF INDIVIDUALS PER UNIT AREA FOR THE TOTALS 149    000600
00405    150*   C     ONLY                                                            150    000600
00405    151*   C                                                                     151    000600
00406    152*   25       DO 27 J=1,NS                                                 152    000602
00411    153*               DO 26 K=1,NSS                                             153    000622
00414    154*               NPA(J,K)=X(J,K)/(AREA*ISS(K))                             154    000622
00415    155*   26          CONTINUE                                                  155    000641
00417    156*   27       CONTINUE                                                     156    000641
00421    157*   28    CONTINUE                                                        157    000641
00422    158*         NSS1=NSS                                                        158    000641
00423    159*         NSS=NSS+1                                                       159    000642
00424    160*         ISS(NSS)=0                                                      160    000644
00425    161*            DO 29 J=1,NSS1                                               161    000706
00430    162*            ISS(NSS)=ISS(J)+ISS(NSS)                                     162    000706
00431    163*   29       CONTINUE                                                     163    000711
00431    164*   C                                                                     164    000711
00431    165*   C     CALCULATE THE TOTAL NUMBER OF INDIVIDUALS PER TAXA              165    000711
00431    166*   C                                                                     166    000711
00433    167*         IF (PROG.EQ.'CSR1  ') GO TO 36                                  167    000711
00435    168*            DO 30 J=1,NS                                                 168    000714
00440    169*            X(J,NSS)=0.                                                  169    000726
00441    170*   30       CONTINUE                                                     170    000735
00441    171*   C                                                                     171    000735
00443    172*            DO 32 K=1,NS                                                 172    000735
00446    173*               DO 31 J=1,NSS1                                            173    000735
00451    174*               X(K,NSS)=X(K,J)+X(K,NSS)                                  174    000735
00452    175*   31          CONTINUE                                                  175    000740
00454    176*            IF (PROG.EQ.'SUBTOT') X(K,NSS)=X(K,NSS)/2                    176    000740
00456    177*   32       CONTINUE                                                     177    000761
00456    178*   C                                                                     178    000761
00460    179*            DO 33 J=1,NS .                                               179    000761
00463    180*            NPA(J,NSS)=X(J,NSS)/(AREA*NSS2)                              180    000761
00464    181*   33       CONTINUE                                                     181    000764
00466    182*         IF (PROG.EQ.'CSR1  ') GO TO 39                                  182    000764
00466    183*   C                                                                     183    000764
00466    184*   C     CALCULATE THE ABSOLUTE ABUNDANCE                                184    000764
00466    185*   C                                                                     185    000764
00470    186*            DO 35 J=1,NS                                                 186    000776
00473    187*               DO 34 K=1,NSS                                             187    000776
00476    188*               AA(J,K)=X(J,K)/X(J,NSS)*100.                              188    000776
00477    189*   34          CONTINUE                                                  189    001012
00501    190*   35       CONTINUE                                                     190    001012
00503    191*         GO TO 39                                                        191    001012
00504    192*   36    CONTINUE                                                        192    001014
```

```
00505            DO 38 K=1,NS                                                    001014
00510            X(K,NSS)=0                                                      001044
00511            ISS(NSS3+1)=0                                                   001045
00512            IP=ISS(1)                                                       001046
00513               DO 37 I=1,NSS3                                               001054
00516               X(K,NSS)=X(K,IP)+X(K,NSS)                                    001056
00517               IP=IP+ISS(I+1)                                               001061
00520    37         CONTINUE                                                     001065
00522            NPA(K,NSS)=X(K,NSS)/(AREA*NSS2)                                 001065
00523    38      CONTINUE                                                        001074
00525    39   CONTINUE                                                           001074
00525    C                                                                       001074
00525    C    CALCULATE THE TOTAL OF THE NUMBER OF INDIVIDUALS PER UNIT AREA     001074
00525    C    FOR EACH STATION                                                   001074
00525    C                                                                       001074
00526         TNPA(1)=0                                                          001074
00527            DO 41 J=1,NSS                                                   001123
00532               DO 40 I=1,NS                                                 001123
00535               TNPA(J)=TNPA(J)+NPA(I,J)                                     001123
00536    40         CONTINUE                                                     001140
00540    41      CONTINUE                                                        001140
00540    C                                                                       001140
00542            DO 43 I=1,NSS                                                   001140
00545               DO 42 J=1,NS                                                 001140
00550               IF (X(J,I).EQ.0.) GO TO 42                                   001140
00552               XS(I)=XS(I)+1.0                                              001141
00553    42         CONTINUE                                                     001156
00555    43      CONTINUE                                                        001156
00555    C                                                                       001156
00555    C    CALCULATE TOTAL NUMBER OF INDIVIDUALS PER STATION                  001156
00555    C                                                                       001156
00557            DO 45 K=1,NSS                                                   001156
00562               DO 44 J=1,NS                                                 001156
00565               XN(K)=XN(K)+X(J,K)                                           001156
00566    44         CONTINUE                                                     001173
00570    45      CONTINUE                                                        001173
00570    C                                                                       001173
00570    C    CALCULATE PROBABILITY OF OCCURANCE FOR INDIVIDUALS                 001173
00570    C                                                                       001173
00572            DO 47 K=1,NSS                                                   001173
00575               DO 46 J=1,NS                                                 001173
00600               XP(J,K)=X(J,K)/XN(K)                                         001173
00601    46         CONTINUE                                                     001211
00603    47      CONTINUE                                                        001211
00603    C                                                                       001211
00603    C    CALCULATE INFORMATION THEORY INDICIES                              001211
00603    C                                                                       001211
00605            DO 49 K=1,NSS                                                   001211
```

```
00610              DO 48 J=1,NS                                                   001211
00613              IF (XP(J,K).LE.0.) GO TO 48                                    001211
00615              H(K)=H(K)+(XP(J,K)*(ALOG10(XP(J,K))/ALOG10(2.0)))              001213
00616      48      CONTINUE                                                       001226
00620           H(K)=-H(K)                                                        001226
00621      49   CONTINUE                                                          001236
00621      C                                                                      001236
00623           DO 50 K=1,NSS                                                     001236
00626           HM(K)=ALOG10(XS(K))/ALOG10(2.0)                                   001236
00627           XHM(K)=XN(K)-XS(K)+1.                                             001244
00630           HMI(K)=(ALOG10(XN(K))/ALOG10(2.))-(XHM(K)/XN(K))*(ALOG10(XHM(K)   001250
00630          1 )/ALOG10(2.))                                                    001250
00631           HE(K)=H(K)/HM(K)                                                  001272
00632           HRR(K)=1.-HE(K)                                                   001275
00633      50   CONTINUE                                                          001306
00633      C                                                                      001306
00633      C    CALCULATE SIMPSON INDEX                                           001306
00633      C                                                                      001306
00635           DC 53 K=1,NSS                                                     001306
00640              DO 51 J=1,NS                                                   001315
00643              SL(K)=SL(K)+(XP(J,K)*XP(J,K))                                  001315
00644      51      CONTINUE                                                       001323
00644      C                                                                      001323
00646              DO 52 J=1,NS                                                   001323
00651              S(K)=S(K)+(X(J,K)*(X(J,K)-1.))                                 001323
00652      52      CONTINUE                                                       001330
00654           S(K)=1.-S(K)/(XN(K)*(XN(K)-1.))                                   001330
00655           SM(K)=(XN(K)*(XS(K)-1.))/(XS(K)*(XN(K)-1.))                       001336
00656           SMI(K)=(2.-(XS(K)/XN(K)))*((XS(K)-1.)/(XN(K)-1.))                 001344
00657           SE(K)=S(K)/SM(K)                                                  001353
00660           SRR(K)=1.-SE(K)                                                   001355
00661      53   CONTINUE                                                          001374
00661      C                                                                      001374
00661      C    CALCULATE MCINTOSH INDEX                                          001374
00661      C                                                                      001374
00663           DC 55 K=1,NSS                                                     001374
00666              DO 54 J=1,NS                                                   001400
00671              UD(K)=UD(K)+(XP(J,K)*XP(J,K))                                  001400
00672      54      CONTINUE                                                       001404
00674           UD(K)=SQRT(UD(K))                                                 001404
00675           U(K)=1.-UD(K)                                                     001412
00676           UM(K)=1.-(1./SGRT(XS(K)))                                         001414
00677           UMI(K)=((XS(K)-1.)+SGRT(XS(K)-1.))/XN(K)                          001425
00700           UE(K)=U(K)/UM(K)                                                  001433
00701           URR(K)=1.-UE(K)                                                   001436
00702      55   CONTINUE                                                          001451
00702      C                                                                      001451
00702      C    WRITE DATA,PROBABILITIES,AND CALCULATIONS                         001451
```

```
00702      C                                                      001451
00704            DO 57 J=1,NS                                     001451
00707              DO 56 K=1,NSS                                  001451
00712              XP(J,K)=XP(J,K)*100.                           001451
00713      56      CONTINUE                                       001460
00715      57    CONTINUE                                         001460
00717          N=1                                                001460
00720      58  NSK=N+1                                            001463
00721          WRITE (6,77) (TITLE(L),L=1,12)                     001465
00724          IF (PROG.EQ.'TOTALS') WRITE (6,105) METHOD,AREA    001475
00731          IF (PROG.EQ.'SUBTOT') WRITE (6,106) METHOD,AREA    001507
00736          IF (PROG.EQ.'CSR1  ') WRITE (6,107) METHOD,AREA    001525
00743          IF (N.EQ.NSS1) GO TO 62                            001537
00745          IF (N.EQ.NSS) GO TO 63                             001542
00747          WRITE (6,78) (STAT(L,N),L=1,5),(STAT(L,NSK),L=1,5) 001545
00761          IF (PROG.EQ.'CSR1  ') GO TO 66                     001571
00763          WRITE (6,95)                                       001574
00765          WRITE (6,93)                                       001601
00767      59  WRITE (6,79)                                       001607
00771            DO 60 J=1,NS                                     001613
00774            WRITE (6,80) J,(SPEC(L,J),L=1,5),(X(J,K),NPA(J,K),XP(J,K),AA(J,   001645
00774         1  K),K=N,NSK)                                      001645
01012      60    CONTINUE                                         001701
01014          WRITE (6,81) (XN(K),TNPA(K),K=N,NSK)               001701
01023      61  CONTINUE                                           001716
01024          WRITE (6,82) (XS(K),K=N,NSK)                       001716
01032          WRITE (6,83) (H(K),K=N,NSK)                        001733
01040          WRITE (6,84) (HM(K),K=N,NSK)                       001746
01046          WRITE (6,85) (HMI(K),K=N,NSK)                      001761
01054          WRITE (6,86) (HE(K),K=N,NSK)                       001774
01062          WRITE (6,87) (HRR(K),K=N,NSK)                      002007
01070          WRITE (6,88) (S(K),K=N,NSK)                        002022
01076          WRITE (6,89) (SL(K),K=N,NSK)                       002035
01104          WRITE (6,90) (SM(K),K=N,NSK)                       002050
01112          WRITE (6,85) (SMI(K),K=N,NSK)                      002063
01120          WRITE (6,85) (SE(K),K=N,NSK)                       002076
01126          WRITE (6,87) (SRR(K),K=N,NSK)                      002111
01134          WRITE (6,91) (U(K),K=N,NSK)                        002124
01142          WRITE (6,92) (UD(K),K=N,NSK)                       002137
01150          WRITE (6,90) (UM(K),K=N,NSK)                       002152
01156          WRITE (6,85) (UMI(K),K=N,NSK)                      002165
01164          WRITE (6,86) (UE(K),K=N,NSK)                       002200
01172          WRITE (6,87) (URR(K),K=N,NSK)                      002213
01172      C                                                      002213
01200          IF (IS.EQ.1) GO TO 71                              002226
01202          IF (NSK.EQ.N) GO TO 63                             002231
01204          N=N+2                                              002234
01205          GO TO 58                                           002237
```

```
01206   337*   62   WRITE (6,113) (STAT(L,N),L=1,5)                                    337   002241
01214   338*        IF (PROG.EQ.'CSR1  ') WRITE (6,115)                                338   002256
01217   339*        IF (PROG.NE.'CSR1  ') WRITE (6,114)                                339   002266
01222   340*        WRITE (6,116)                                                      340   002276
01224   341*        NSK=N                                                              341   002303
01225   342*        IF (PROG.EQ.'CSR1  ') GO TO 67                                     342   002305
01227   343*        GO TO 59                                                           343   002310
01230   344*   63   CONTINUE                                                           344   002312
01231   345*        NSK=N                                                              345   002312
01232   346*        IS=1                                                               346   002313
01233   347*        IF (NSK.EQ.NSS) GO TO 64                                           347   002315
01235   348*        WRITE (6,77) (TITLE(L),L=1,12)                                     348   002317
01240   349*        IF (PROG.EQ.'CSR1  ') WRITE (6,107) METHOD,AREA                    349   002327
01245   350*        IF (PROG.EQ.'CSR1  ') GO TO 69                                     350   002341
01247   351*        IF (PROG.EQ.'TOTALS') WRITE (6,105) METHOD,AREA                    351   002344
01254   352*        IF (PROG.EQ.'SUBTOT') WRITE (6,106) METHOD,AREA                    352   002356
01261   353*   64   CONTINUE                                                           353   002371
01262   354*        IF (PROG.EQ.'CSR1  ') GO TO 69                                     354   002371
01264   355*        WRITE (6,94)                                                       355   002403
01266   356*        WRITE (6,99)                                                       356   002412
01270   357*        WRITE (6,79)                                                       357   002417
01272   358*           DO 65 J=1,NS                                                    358   002434
01275   359*           WRITE (6,100) J,(SPEC(L,J),L=1,5),X(J,NSS),NPA(J,NSS),XP(J,NSS) 359   002434
01307   360*   65      CONTINUE                                                        360   002454
01311   361*        WRITE (6,101) XN(NSS),TNPA(NSS)                                    361   002454
01315   362*        NSK=NSS                                                                  002463
01316   363*        N=NSS                                                                    002465
01317   364*        GO TO 61                                                           362   002466
01320   365*   66   CONTINUE                                                           363   002470
01321   366*        WRITE (6,108)                                                      364   002470
01323   367*        WRITE (6,93)                                                       365   002474
01325   368*        WRITE (6,79)                                                       366   002501
01327   369*   67   CONTINUE                                                           367   002507
01330   370*           DO 68 J=1,NS                                                    368   002507
01333   371*           WRITE (6,104) J,(SPEC(L,J),L=1,5),(X(J,K),NPA(J,K),XP(J,K),K=N, 369   002534
01333   372*      1    NSK)                                                            370   002534
01350   373*   68      CONTINUE                                                        371   002564
01352   374*        WRITE (6,110) (XN(K),TNPA(K),K=N,NSK)                              372   002564
01361   375*        GO TO 61                                                           373   002600
01362   376*   69   CONTINUE                                                           374   002602
01363   377*        WRITE (6,109)                                                      375   002602
01365   378*        WRITE (6,99)                                                       376   002606
01367   379*        WRITE (6,79)                                                       377   002613
01371   380*           DO 70 J=1,NS                                                    378   002620
01374   381*           WRITE (6,112) J,(SPEC(L,J),L=1,5),X(J,NSS),NPA(J,NSS),XP(J,NSS) 379   002637
01406   382*   70      CONTINUE                                                        380   002657
01410   383*         NSK=NSS                                                                 002657
01411   384*        N=NSS                                                                    002661
```

```
01412        WRITE (6,101) (XN(K),TNPA(K),K=N,NSK)                       002662
01421        GO TO 61                                                    002700
01422  71    WRITE (6,97)                                                002702
01424        STOP                                                        002706
01424  C                                                                 002706
01424  C     FORMAT STATEMENTS                                           002706
01424  C                                                                 002706
01424  C                        *****FORMAT STATEMENTS*****              002706
01424  C                                                                 002706
01425  72    FORMAT (' ','PROG=',2X,A6)                                  002712
01426  73    FORMAT (12A6)                                               002712
01427  74    FORMAT (2I5,2X,A6,2X,A6)                                    002712
01430  75    FORMAT (5A6,I2)                                             002712
01431  76    FORMAT (13A6,A2)                                            002712
01432  77    FORMAT ('1',T28,12A6)                                       002712
01433  78    FORMAT ('0',//35X,5A6,29X,5A6)                              002712
01434  79    FORMAT (1X,/)                                               002712
01435  80    FORMAT (' ',I3,2X,5A6,F7.0,5X,3F10.2,5X,F10.0,5X,3F10.2)    002712
01436  81    FORMAT ('0TOTAL INDIVIDUALS',15X,F10.0,5X,F10.2,25X,F10.0,5X,  002712
01436       1F10.2)                                                      002712
01437  82    FORMAT ('0TAXA PRESENT',T34,F10.0,T84,F10.0)                002712
01440  83    FORMAT ('0SHANNON INDEX d̄ ',T38,F10.4,T88,F10.4)            002712
01441  84    FORMAT (' RELATIVE MAXIMUM',T38,F10.4,T88,F10.4)            002712
01442  85    FORMAT (' RELATIVE MINIMUM',T38,F10.4,T88,F10.4)            002712
01443  86    FORMAT (' EFFICIENCY',T38,F10.4,T88,F10.4)                  002712
01444  87    FORMAT (' REDUNDANCY',T38,F10.4,T88,F10.4)                  002712
01445  88    FORMAT ('0SIMPSON INDEX S',T38,F10.4,T88,F10.4)             002712
01446  89    FORMAT (' SIMPSON LAMDA',T38,F10.4,T88,F10.4)               002712
01447  90    FORMAT (' RELATIVE MAXIMUM',T38,F10.4,T88,F10.4)            002712
01450  91    FORMAT ('0MCINTOSH INDEX U',T38,F10.4,T88,F10.4)            002712
01451  92    FORMAT (' MCINTOSH DELTA',T38,F10.4,T88,F10.4)              002712
01452  93    FORMAT (' ',31X,'INDIVIDUALS',3X,'PER SQUARE METER',23X,    002712
01452       1'INDIVIDUALS',3X,'PER SQUARE METER')                        002712
01453  94    FORMAT ('0',//47X,'TOTAL OF ALL STATIONS',/'0      TAXA    ',T33,  002712
01453       1'  TOTAL NO.',9X,'NO. INDIVIDUALS',4X,'RA')                 002712
01454  95    FORMAT ('0      TAXA    ',25X,'NO.',6X,'NO. INDIVIDUALS',3X,'RA',8X,  002712
01454       1'AA',13X,'NO.',6X,'NO. INDIVIDUALS',3X,'RA',6X,'AA')        002712
01455  96    FORMAT (2I5,2X,A6,F10.6,2X,A6)                              002712
01456  97    FORMAT ('1')                                                002712
01457  98    FORMAT ('0',25F5.0)                                         002712
01460  99    FORMAT (' ',32X,'OF INDIVIDUALS',5X,'PER SQUARE METER')     002712
01461  100   FORMAT (' ',I3,2X,5A6,F7.0,12X,2F10.2)                      002712
01462  101   FORMAT ('0TOTAL INDIVIDUALS',15X,F10.0,12X,F10.2)           002712
01463  102   FORMAT (16I5)                                               002712
01464  103   FORMAT ('1ERROR: PROG NOT READ IN CORRECTLY')               002712
01465  104   FORMAT (' ',I3,2X,5A6,F7.0,5X,2F10.2,T87,F7.0,7X,2F10.2)    002712
01466  105   FORMAT (' ',36X,'TOTALS',15X,A6,5X,'AREA=',F10.5,1X,'SQUARE METERS  002712
01466       1')                                                          002712
```

```
01467     433*     106   FORMAT (' ',29X,'SUBTOTALS AND TOTALS',7X,A6,5X,'AREA=',F10.6,1X,    429     002712
01467     434*          1' SQUARE METERS')                                                     430     002712
01470     435*     107   FORMAT (' ',21X,'CUMULATIVE SUMS OF REPLICATES',6X,A6,5X,'AREA=',     431     002712
01470     436*          1F10.6,1X,'SQUARE METERS')                                             432     002712
01471     437*     108   FORMAT ('0      TAXA    ',24X,'NO.',6X,'NO. INDIVIDUALS',5X,'RA',    433     002712
01471     438*          1T88,'NO.',9X,'NO. INDIVIDUALS',3X,'RA')                               434     002712
01472     439*     109   FORMAT ('0',//47X,'TOTAL OF ALL STATIONS',/'0      TAXA    ',23X,     435     002712
01472     440*          1'TOTAL NO.',10X,'NO. INDIVIDUALS',9X,'RA')                            436     002712
01473     441*     110   FORMAT ('0CUMULATIVE SUMS OF REPLICATES',3X,F10.0,5X,F10.2,T84,      437     002712
01473     442*          1F10.0,7X,F10.2)                                                       438     002712
01474     443*     111   FORMAT (5A6)                                                          439     002712
01475     444*     112   FORMAT (' ',I3,2X,5A6,F7.0,12X,F10.2,7X,F10.2)                        440     002712
01476     445*     113   FORMAT ('0',//35X,5A6)                                                441     002712
01477     446*     114   FORMAT ('0      TAXA    ',25X,'NO.',6X,'NO. INDIVIDUALS',3X,'RA',8X,  442     002712
01477     447*          1'AA')                                                                 443     002712
01500     448*     115   FORMAT ('0      TAXA    ',24X,'NO.',6X,'NO. INDIVIDUALS',5X,'RA')     444     002712
01501     449*     116   FORMAT (' ',31X,'INDIVIDUALS',3X,'PER SQUARE METER')                  445     002712
01502     450*     117   FORMAT ('0DATA CARD NOT READ IN CORRECTLY.  CHECK THE CARD TO READ   446     002712
01502     451*          1NS,NSS,PROG,METHOD')                                                  447     002712
01502     452*     C                                                                           448     002712
01503     453*           END                                                               449-    002712
END FOR

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